

The ninth magnitude star W^1 x. 234, about $4'$ distant in the direction of 290° , has a still larger proper motion, but in nearly the opposite direction. Porter gives this movement from meridian observations as $0''.495$ in $270^\circ.9$. The micrometrical measures of this star from γ *Leonis* by $O\Sigma$ give substantially the same value.

Yerkes Observatory :
April 26.

Photographs of the Nebulae in the Pleiades, of Stars in the Surrounding Regions and of Spurious Nebulosity. By Isaac Roberts, D.Sc., F.R.S.

The photographs annexed are prints from the original negatives, which were taken with the 20-inch reflector and the Cooke 5-inch lens respectively, the exposures of the plates being simultaneous during ten hours. 1st, on 1897 December 22, during $3^h 20^m$; 2nd, on the 23rd, during $3^h 0^m$; 3rd, on the 25th, during $3^h 40^m$ —three exposures during an interval of four days. The sky on each occasion was very clear.

Scale of the reflector photograph, 1 millimetre to 81.45 secs. of arc.

Scale of the lens photograph, 1 millimetre to 415 secs. of arc.

On examination of the reflector photo-negative, it is seen that the *Merope* nebula extends from that star to the distance of about 40 minutes of arc, and faintly covers an area of about the same width, in the *south*, *south preceding*, and *south following* directions; the *Maia* nebulosity also extends about 40 minutes of arc in the *nf* direction. The other stars and the nebulosities, which together form the group of the *Pleiades*, and were depicted on my photograph of 1888 December 8, are shown with but little further extensions or obvious changes of form during the nine years' interval, though the density is greater on the present one owing to the longer exposure.

The photograph taken with the 5-inch lens covers an area of the sky measuring about 17° by 17° , of which a little over 10° by 10° are shown annexed, with *Alcyone* in the centre, and it will be observed that the group of the *Pleiades* is completely obscured by the photographic effects of atmospheric glare, to which reference will be made further on. All the stars brighter than the 11th magnitude are, on the negative, visible through the glare; but the fainter stars, together with the known real nebulosities, are entirely obliterated because their light is feebler than that of the glare itself.

Other photographs of this group and of the surrounding regions were also taken with the 20-inch reflector, and simultane-

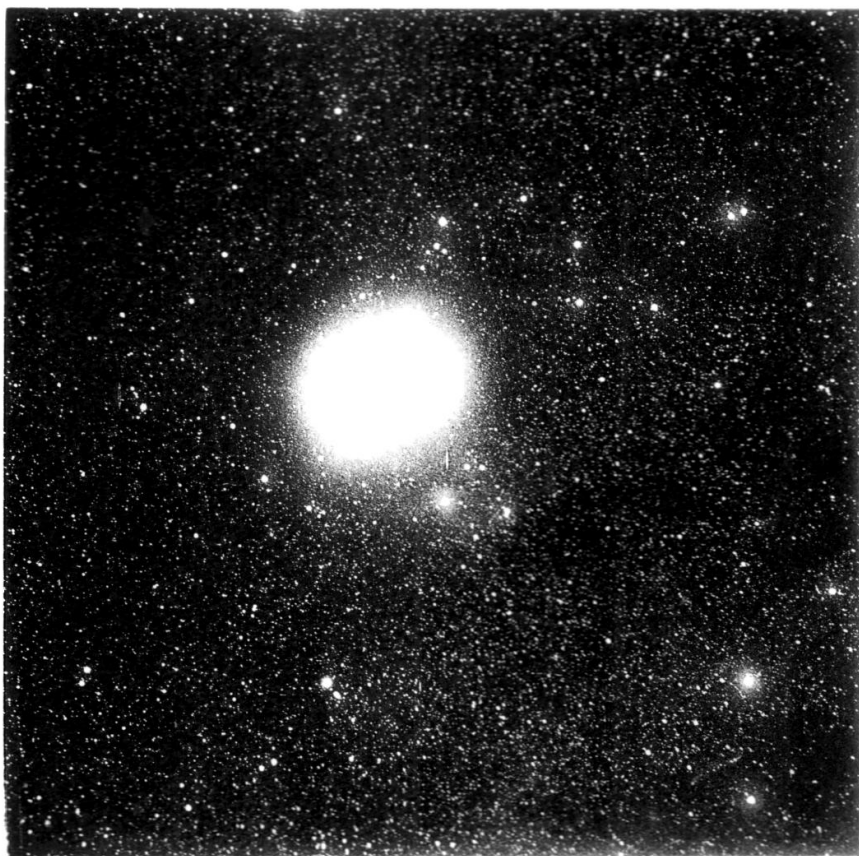
PHOTOGRAPH OF THE PLEIADES

20 in. Reflector—Exposure 10 h.

1



2



PHOTOGRAPH OF THE PLEIADES

5 in. Lens—Exposure 10 h.

ously with the 5-inch lens, on 1897 October 28, with an exposure of the plate during eight hours, and on 1897 November 19 to 22, with aggregate exposures of the plate during 9^h 2^m. Besides these, several photographs with exposures of the plates during intervals varying between one minute and four hours respectively have been taken during the past ten years.

The descriptive matter following relates to the reflector-photograph annexed hereto, and shown on the screen, as well as to the other two with long exposures, referred to above.

The nebula round *Merope* is of a streaky character, with the star in the centre of the denser part: the streaks trend in *south following* to *north preceding* directions for a distance of about 16 minutes of arc, and then curve in the direction *south preceding*, where the nebulosity becomes very faint but still streaky in character, and spreads out to the extent of 50 minutes of arc in breadth. It does not seem to commingle in any degree with the other adjacent nebulosities, and there are four faint stars involved in it within a distance of 60 seconds of arc from *Merope*. Besides these, there are other bright and faint stars involved in the nebulosity.

A straight streak of dense nebulosity extends across the two stars 1 and 7 (*Bessel*): it is about 19 minutes of arc in length, and does not seem to form a part of any of the other nebulosities. I infer that it is an independent nebula seen edgewise, and there is a bright star at its centre and three faint stars apparently involved.

Electra does not seem to be involved in nebulosity, but there is a streak of strong nebulosity extending to a distance of about 14 minutes of arc from it towards the *following* direction, and it is divided along its full length into two equal parts by a faint dark streak. Six stars of between 13th and 16th magnitudes are apparently involved in this nebula, which is seen edgewise, and is, I think, independent of the others. The nebulosity which extends from *Maia* crosses the streak above referred to at an angle of 45°, but no physical result seems to have been caused by this, which confirms the idea of the separate existence of both nebulae.

Alcyone is surrounded by nebulosity of both a streaky and flocculent character. The streaks on the *following* side trend *south following* to *north preceding*, and those on the *preceding* side cross the streaks of the *Maia* nebula at nearly right angles, without appearance of either disturbance or of commingling. This again points to the nebulae being independent. To the north of *Alcyone* is a streak of nebulosity 30 minutes of arc in length, slightly curved towards the north, and involves the stars 10 and 24 (*Bessel*), besides twelve other stars of between 12th and 18th magnitudes. This appears to be an independent nebula seen edgewise, and is probably of a spiral character. The north part of the *Alcyone* nebula seems to cross this streak without causing any disturbance to either of them.

Maia is surrounded by streaky nebulosity trending north and south in parts, and *north following* to *south preceding* in other parts. To the *north following* it extends in a long streaky arm a little beyond the star 12 (*Bessel*)—a distance of about 44 minutes of arc, and on the *north preceding* side reaches *Taygeta*. There is also evidence of very faint nebulosity extending 30 minutes of arc on the *south following* side towards *Maia*.

No clear proof is given that *Pleione* and *Atlas* are involved in nebulosity.

It appears to me that the evidence, taken as a whole, points strongly to the probability that the *Pleiades* consist of a group of stars seen by us either behind or else in front of a group of nebulae, *Alcyone*, *Merope*, and *Maia* being involved in nebulosity; but at present there is no indication of physical connection between the other nebulae and these three, or with each other. I may further add that it will be an exceedingly difficult work to extend materially the knowledge we now possess concerning the group until movements, and changes of structure, can be detected amongst its components.

I shall here draw attention to a paper by Professor Barnard, published in the *Monthly Notices* of this society, vol. lvii. pp. 10–16. On p. 14 he states: “At a meeting of the B.A.A. on April 29 Dr. Roberts took a further opportunity to object to these star pictures, and is reported to have said the exterior nebulosities shown on my *Pleiades* photographs were not nebulosity, and he made the assertion without fear of anyone proving the contrary. . . . That these nebulosities exist as shown on my photographs there can be no doubt whatever.”

A copy of the photograph referred to and also a diagram-sketch are appended to his paper; and his photo-copy of the original negative is placed in the archives of the Society, and will now be shown on the screen. Those who will take the trouble to examine these photographs will be struck with the very coarse character of the film; with the distorted images of the stars; with the halation circles round the brighter stars, caused by the omission of backing the plate; and with the large patch of something (stated to be nebulosity) covering the group of the *Pleiades*; and it is upon this one defective photograph that Professor Barnard bases his unqualified assertion that there is no doubt whatever that these nebulosities exist as shown on his photograph. The vague suggestion of visibility in a telescope is quite inadmissible so long as the bright nebulosities known to exist in the group cannot be seen.

The six photographs (three with the reflector and three with the 5-inch lens) which have been taken at my observatory between 1897 October 28 and December 1—a copy of the latter being hereto annexed—entirely discredit the existence of Professor Barnard's nebulosity. These photographs were taken with proper care; the star images are not distorted; there is no halation effect; the sky was clear during the various exposures of the

plates, and the exposures were equal as regards photographic effect, for the stars and nebulosities shown on the plate with 10 hours are also shown on the 9^h 2^m and on that with 8 hours' exposure.

I must further remark on Professor Barnard's paper that in it he misquotes from my work—misconstrues my statements—gives measurements of the distances of certain nebulæ, on two of his photographs, which are in error to the extent of so much as $2\frac{1}{2}$ degrees in 8 degrees on one, and 53 minutes in 4 degrees on the other; counts stars on a plate I have never seen, and of which I know nothing, then by this insinuates that my count of the stars on another plate, which he sent to this Society, cannot be correct; states that I have distinctly denied the existence of nebulosity in certain parts of the sky, whereas the reverse of this is true—for I have shown and published not only the existence but also the structural details of the nebulosity. This list does not exhaust the statements contained in the paper that require correction.

When very sensitive gelatine plates have been exposed to the sky during several hours they are liable to show, after development, dark patches of unequal density on various parts of the films, the light and dark parts presenting the appearance of nebulosity. These appearances may be caused by imperfections in the lenses used; by coarseness of grain and irregularities in the films; by insufficient cleaning or of smears on the plates; by slowly passing clouds during the exposures, or by omission of simultaneously flooding the films in developing the plates. The appearances may also be intensified by moonlight, or by omitting to back the plates, with a non-reflecting material, to prevent the effects of reflections of starlight (halation) from the back of the negatives. In making positive, or contact, copies of such negatives the film defects referred to are greatly intensified, and during the correlative operations the appearances of spurious nebulosity are also intensified.

Besides these mechanical defects there is the physical cause, due to illumination by starlight of the Earth's atmosphere, which affects the sensitive films during long exposures of the plates. This produces those appearances of spurious nebulosity in which the stars in the Milky Way seem to be immersed, and is one of the chief causes that mislead the inexperienced in stellar photography.

The scale of the photographs taken with portrait lenses of 6 inches aperture and under being small, and the photo-images of the bright stars relatively large, the stars down to the 4th or 5th magnitude to which the photo-plates have been exposed during intervals of from 4 to 10 hours have their photo-images involved in circles of apparent dense nebulosity—and all forms of instruments show these effects—which in reality are due to the atmospheric illumination by the light of the stars and to

diffraction. A similar effect is often visible to sight round the Sun, Moon, and bright stars.

The bright stars which form the group of the *Pleiades* when photographed on the small scale of portrait-lens pictures with exposures of the plates during eight or ten hours will, after development, appear as black spots in the midst of atmospheric glare, and not a trace of the real nebulosities, known to exist in the group, can be detected upon them. Thus also in the case of those vast areas of bright and faint stars in the Milky Way, and in other crowded star areas, when they are photographed on the small scale of portrait-lenses, have their aggregate light, which illuminates the Earth's atmosphere over the area photographed, concentrated by the lens upon the photo-film, and thus producing the appearance of the stars being immersed in nebulosity. The contiguous areas in the sky, that are in the field of the lens and have few stars upon them, add to the illusion of nebulosity by causing structural features in the atmospheric glare.

The diffused starlight of the sky, even on dark clear nights, has a powerful effect upon very sensitive photo-films, and I have made several experiments in order to enable me to judge its relative intensity during long exposures of the plates simultaneously in the reflector, in the 5-inch lens camera, and inside a blackened box 6 inches square by 12 inches in height with the open end pointed to the zenith. Parts of the plates in the box were exposed to the sky uncovered, whilst other parts were covered with black paper or with rectangular pieces of polished plate-glass of various thicknesses between 5·63 and 45 millimetres. Exposures were also made under sensitometer scales. By combinations of these methods I have been enabled to estimate the photographic effects of the atmospheric glare upon sensitive films exposed simultaneously in the 20-inch reflector, the 5-inch lens, and to the open sky, under precisely similar conditions as to quality of the sky, duration of exposure, equality in the sensitiveness of the plates, and similarity in the development.

The results showed that the uncovered parts of the films placed in the box were darkened by the sky glare to about the density of the photo-images of stars of the 16th magnitude as they appear after exposures of two and a half hours in the 20-inch reflector, whilst the parts covered with black paper were unaffected, and after development the films were as clear as the glass plates. The parts of the films that were covered with plate-glass had gradations in the photo-density proportional to the absorption and reflection from the surfaces of the light by the respective thicknesses of the plates of glass.

The bearings of these results upon stellar photographs by assisting in the production of appearances of spurious nebulosity are obvious; and it is to the causes referred to in the foregoing paragraphs that the erroneous ideas of the existence of enormous fields of nebulosity in and about the Milky Way have been generated.

Where real nebulosity exists it is confined to areas relatively small, seldom exceeding two or three degrees in extent.

The evidence now laid before us may be applied to the interpretation of the large areas of so-called nebulosity shown on many photographs that have been presented to the Society or published in *Knowledge* and in other serials.

Referring again to the six photographs of the *Pleiades* that were taken with the reflector and the 5-inch lens, with exposures respectively of 8^h, 9^h 2^m, and 10^h, it is found that upon those taken with the 5-inch lens the faint stars which are shown on Professor Barnard's photograph with 10 $\frac{1}{4}$ hours' exposure are also shown, but no trace whatever is there of what he designates as the distant nebulosity. But on the photographs taken simultaneously with them by the 20-inch reflector there is much spurious nebulosity visible; and that it is spurious, and not real, is proved by the fact that, though it appears on each of the three photographs, it does not coincide, either in density, or in position, or in extent, on any of the plates. This could not happen if it were due to real nebulosity, or to concentrated starlight, or even to defects in the lenses; it must be due to chemical and to atmospheric causes, for otherwise the photo-effects would be alike on each of the plates.

The spurious nebulosity is shown in cloud-like patches, and simulates the real nebulosity so closely that its true character could not be decided, with certainty, without the careful correlation of two or more photographs taken at different times of the same areas in the sky.

A Determination of the Proper Motions of the Greenwich Clock Stars from the Greenwich Transit Circle Observations, 1854-1896. By W. G. Thackeray.

The old Greenwich observations of right ascension are, as is well known, affected by systematic errors due to imperfect clock-star places. To get rid of these errors the places of the clock stars for the last twenty-five years have been specially corrected to the results of the 12-hour groups, with what marked success the 1880 and 1890 catalogues have fully demonstrated. To eliminate these errors in a perfectly orthodox method requires a large amount of honest labour, while the application of arbitrary corrections is not altogether satisfactory. As the Greenwich Transit Circle has been in constant use for nearly half a century, and a considerable number of observations of the clock stars have been made with it during this period on a uniform system, it seemed well worth while to discuss the series of observations with a view to compare the results thus obtained with those derived from much longer and varied series by Professors Auwers and Newcomb.